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DIRECT PICK-UP INTERFERENCE

SUBJECTIVE TESTS

October 12, 1993

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Introduction and Background

In 1986, CBS Laboratories, in conjunction with the National Association of Broadcasters, performed a series of subjective interference tests. One was a *"just perceptible"* co-channel interference test (a repeat of the well known "W" curve) with undesired signals spaced at intervals of 500 kHz. The desired signals were on UHF channel 23 whose visual carrier is at 525.5 MHz. In another, two undesired, co-channel signals were located near the visual subcarrier (500 kHz above) and the color subcarrier (100 kHz below). For the co-channel luminance interference the *"just perceptible"* level was found to be 63.5 dB on pictures and 68.65 dB on a 50-IRE-unit grey field. Picture quality was judged to be *"acceptable"* when the D/U was 62 dB. For co-channel chrominance interference, the *"just perceptible"* level was 58 dB on pictures and 62dB on 50-IRE grey, while *"acceptable"* picture quality was at 56.5 dB (see attachment A). One conclusion drawn from this study was that any worsening of the D/U resulted in less than *"acceptable"* reception. There was a sharp transition (almost no range) from *"acceptable"* to *"unacceptable"*, unlike what happens with random noise. The range was only 1.5 dB between *"just perceptible"* and *"acceptable"* in both cases. Stated another way, just past the point at which the interference was perceived, it was quickly (i.e. in 2 to 3 dB) judged unacceptable.

This new subjective study of direct pickup (DPU) interference was designed to establish and describe some "anchor points" to ground the Carl T. Jones Corp. (CTJC) objective 55 dB D/U *"just perceptible"* level to contemporary viewer sensitivities and to add subjective definition to the CTJC "Figure of Merit". It was designed also as a cross-check on the previous work of CBS/NAB to determine if the findings change over time.

Test Procedure

The equipment, receiver type and orientation etc. for the present study are described in detail in the CTJC report. The viewers stood or were seated in front of a 27-inch color television receiver from the objective tests, at viewing ratios of five- and four-times picture height respectively. Ambient illuminance, per CCIR viewing specifications, was low with back-lighting behind the display and neutral grey/off-white walls.

The test method was similar to the ascending/descending approach which is used to determine thresholds of perception as in hearing testing. The viewers for this study, six expert observers from the industry, determined the *"just perceptible"* points using the descending direction. They reduced the level of interference from a clearly perceptible level until a consensus was reached that the DPU interference was *"just perceptible"*. After each four 50-dB C/N trials, the viewers were presented with a 55 dB D/U at each channel and frequency used by CTJC for their objective measurements, and asked to rate the interference on a graphic scale of the CCIR impairment terms. A total of 140 judgments was made.

The desired signal was a 50-IRE-unit grey field as it was in the 1986 CBS/NAB study. The desired signal level was held constant at 0 dBmV. The undesired signal was a conducted DPU interference at those levels and channels used by CTJC, incorporating three channels at two carrier-to-noise ratios. Four frequencies within the 6-MHz channels were examined: visual carrier (VC) +0.25 MHz, VC+0.75 MHz, VC+1.75 MHz, and VC+2.55 MHz, the final frequency being the one also used in the CTJC objective measurements at a D/U of 55 dB. The interference appears on the screen as patterns which transition from a "thumb-print" wavy line appearance to a "basket-weave" pattern. The visibility of a particular interfering pattern depends upon its relationship to the horizontal sync sidebands. Impairments falling on a sideband are most visible, and those falling midway between sidebands are least visible. It was expected that the 43 dB C/N level would result in higher *"just perceptible"* interference levels (i.e. smaller D/Us) due to noise masking, i.e. the noise hiding the presence of the interference. If the desired signal is strong and clear, such as at 50-dB C/N, the interference should be seen at lower interference levels (i.e. larger D/Us).

Results

The results section of this report and the Figures are presented in terms of undesired-to-desired (U/D), the reciprocal of D/U, for ease of interpretation. This merely means that the values become negative; the actual numbers remain the same.

Figure 1 is the 1986 CBS/NAB "W" contour. The three curves represent a grey field, a still-test picture and a motion-test picture. Since only slight differences were found, the new DPU subjective tests used only a 50-IRE-unit grey field. In the former study the desired signal level was -55 dBm which is equivalent to -6.25 dBmV and produces a rather poor and noisy signal. The current study employed 0 dBmV which is better, but not noise free, and also, in an abbreviated test, +10 dBmV which provides a good, fairly strong, signal.

The test results for Channel 6, (VC at 83.25 MHz), are shown in Figure 2, plotted with the 1986 CBS/NAB 50-IRE-unit data for comparison. Channel 6 reception was tested with a desired signal level of 0 dBmV and C/Ns of 50 and 43 dB. On the 50-dB more noise-free display, the DPU interference is perceived at lower signal interference levels than when it is apparently masked by the noise at a C/N of 43 dB. In general, in the Channel 6 test, DPU is visible at higher levels than in the Channel 23 UHF co-channel interference test. The -55 dB U/D point at VC+2.55 MHz used for the CTJC objective tests is marked on the display with a large dot. It was rated mid-way between *"Imperceptible"* and *"Perceptible but not Annoying"* on the graphic scale, the point where a true perception threshold would be expected to fall.

The test results for Channel 12, (VC at 205.25 MHz), are shown in Figure 3 along with the earlier 50-IRE-unit data. Channel 12 reception was also tested at 0 dBmV with C/Ns of 50 and 43 dB. There is very little difference between the noisy and noise-free displays. In general, the DPU is visible at about the same levels as it was in the earlier CBS/NAB tests. The -55 dB U/D point at VC+2.55 MHz used for the CTJC objective tests marked on the display with a large dot was rated just below *"Perceptible, but not Annoying"*.

The test results for Channel 78, (VC at 547.25 MHz), are shown in Figure 4. Channel 78 reception was also tested at 0 dBmV with C/Ns of 50 and 43 dB. On the more noise-free displays with 50-dB C/N, the DPU interference was again seen at lower levels than when it was masked by the 43-dB C/N. In general, the DPU is visible at about the same levels as the earlier study had found with the possible exception of VC+2.55 MHz which was not tested in the 1986 study. The -55 dB U/D point at VC+2.55 MHz used for the CTJC objective tests (marked on the display with a large dot) was rated just above *"Perceptible, but not Annoying"*.

The test results for Channels 6 and 12 with the desired signal level increased (i.e. improved) to +10 dBmV are presented in Figures 5 and 6. When looking at Channel 6, DPU interference was seen at lower levels at +10 than at 0 dBmV, presumably due to a freeing-from-masking effect. In general, the DPU interference is visible at about the same levels as the co-channel interference was in the earlier study. The -55 dB U/D point at VC+2.55 MHz used for the CTJC objective tests was rated *"Slightly Annoying"* under these conditions for the same reason, i.e. a lack of masking in the better signals. This masking effect is not apparent on Channel 12, where DPU interference was seen at levels quite intermingled with the other data, and the -55 dB U/D point was rated just better than *"Perceptible, but not Annoying"*.

The graphic-scale ratings of the -55 dB U/D test points are shown in Figure 7. The levels of all the test conditions on each channel are summarized in Table 1.

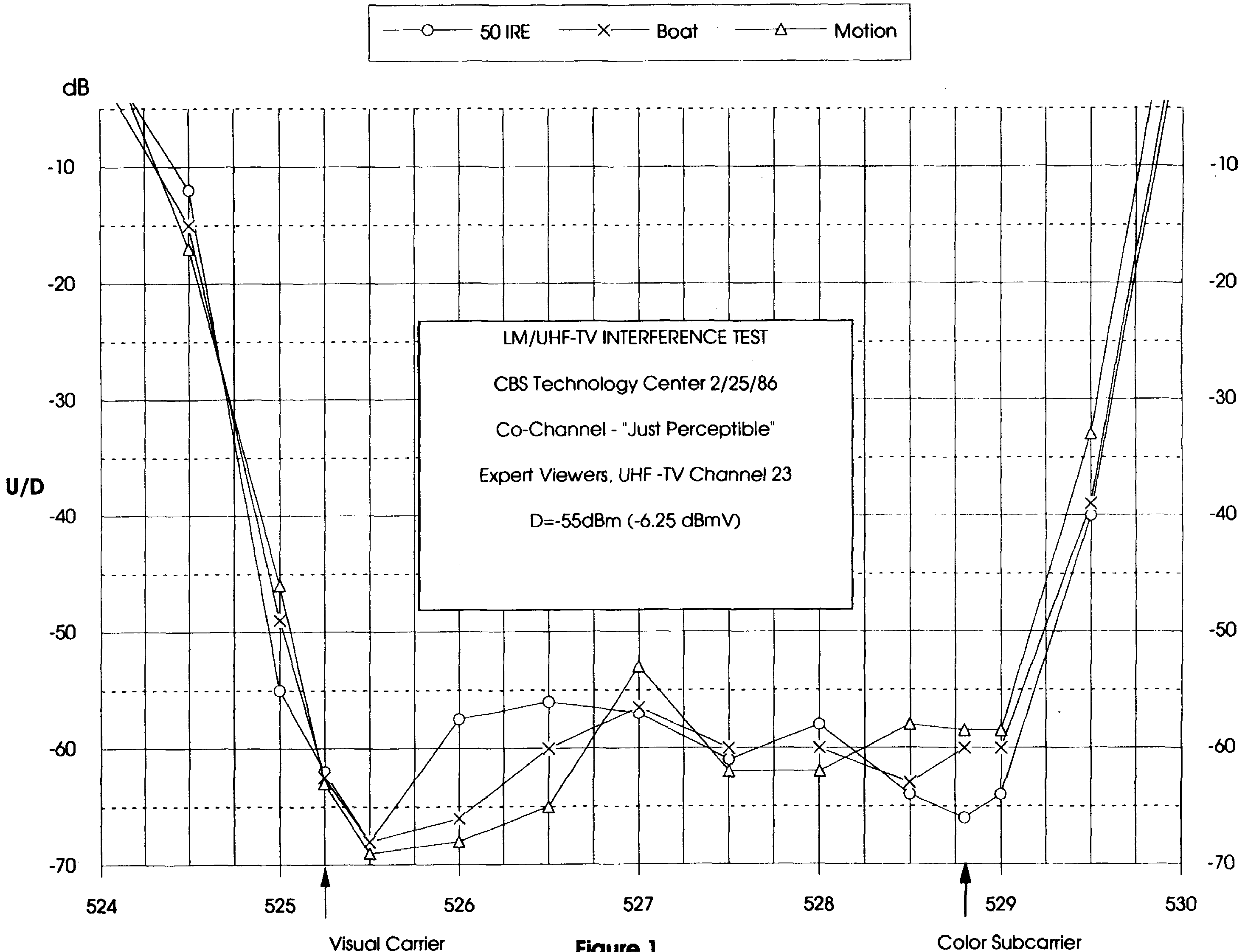
Conclusions

Clearly viewer sensitivities to this interference at *"just perceptible"* do not shift over time as do viewer opinions of picture quality. This can be explained by the fact that visual thresholds are being tested, not subjective opinions. Visual systems are not changing; however, technology and viewer expectations are.

The conclusion that any worsening of the interference level beyond *"just perceptible"* results in less than *"acceptable"* reception was again observed by the viewers and experimenters. Perhaps because the interference shows up in such definite patterns, it becomes objectionable very quickly.

The -55 dB U/D (55 dB D/U) test points, when presented blind to the viewers, were generally rated *"perceptible, but not annoying"*. It is reasonable to assume that this is equivalent in meaning to *"just perceptible"*.

It has been clearly demonstrated once again that a D/U of 55 dB is a good nominal visual threshold value for use as a reference, yardstick and/or anchor point.



50 IRE
Boat
Motion
dB
U/D
-10
-20
-30
-40
-50
-60
-70
LM/UHF-TV INTERFERENCE TEST
CBS Technology Center 2/25/86
Co-Channel - "Just Perceptible"
Expert Viewers, UHF -TV Channel 23
D=-55dBm (-6.25 dBmV)
524
525
526
527
528
529
530
Visual Carrier
Color Subcarrier

Figure 1

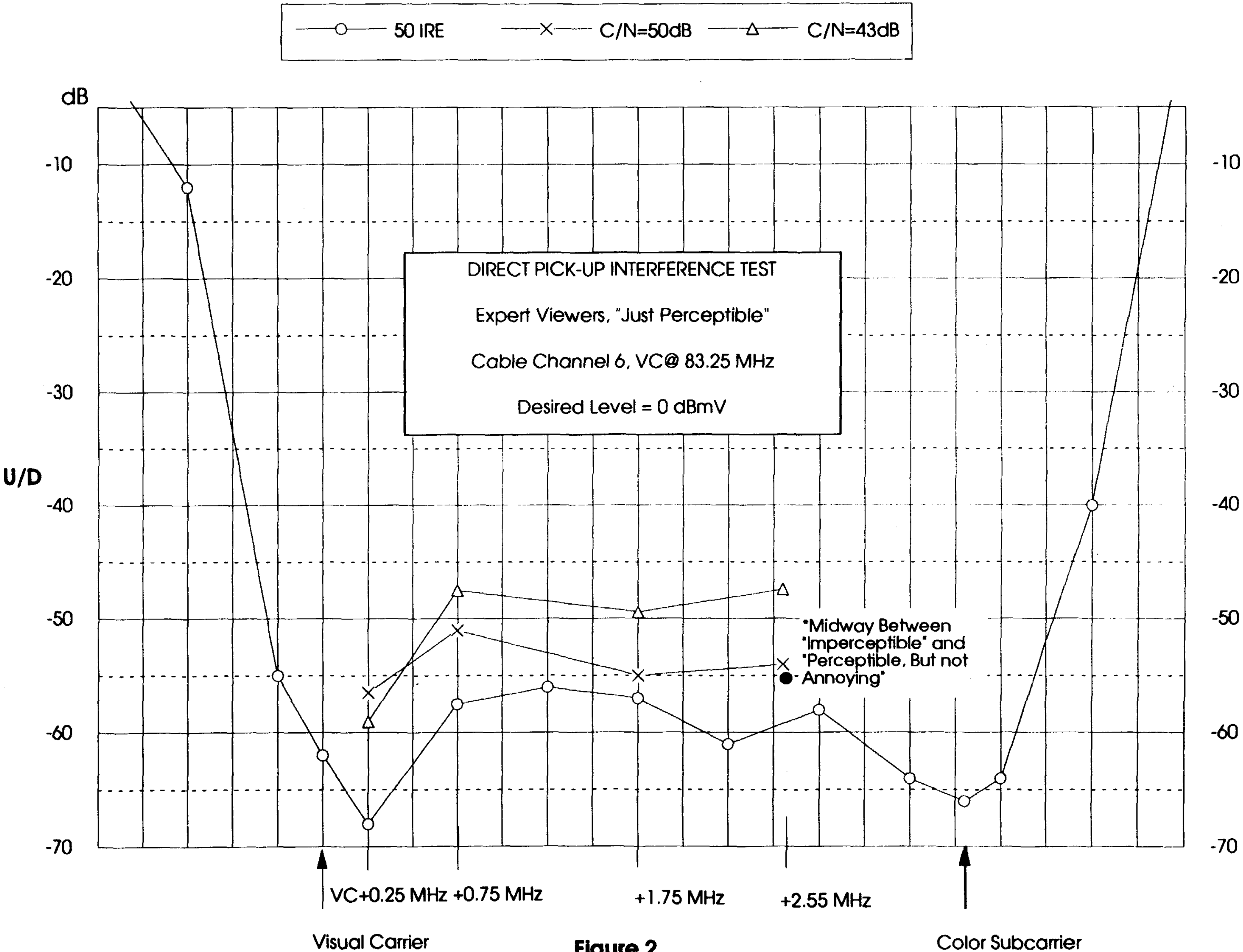
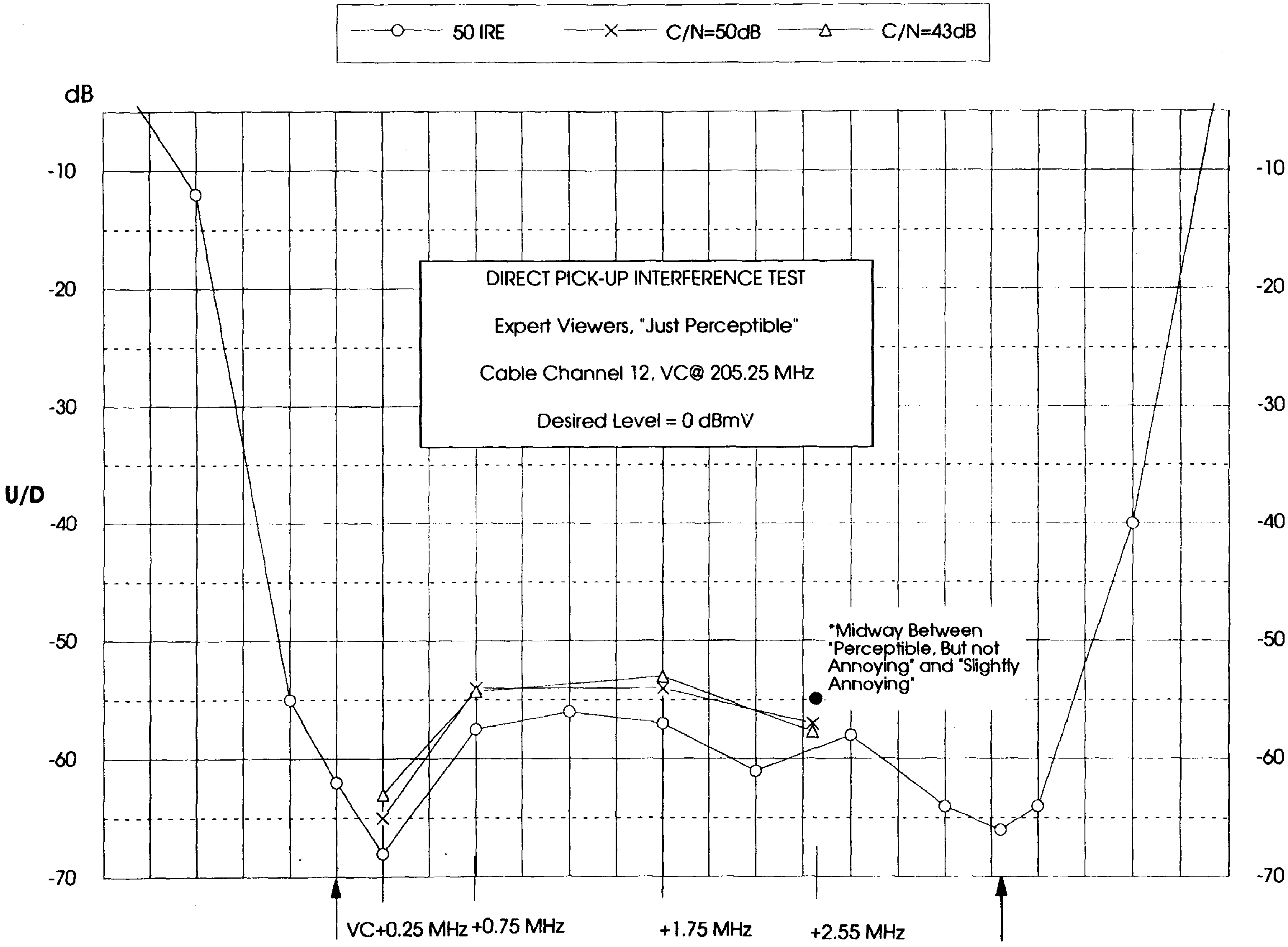
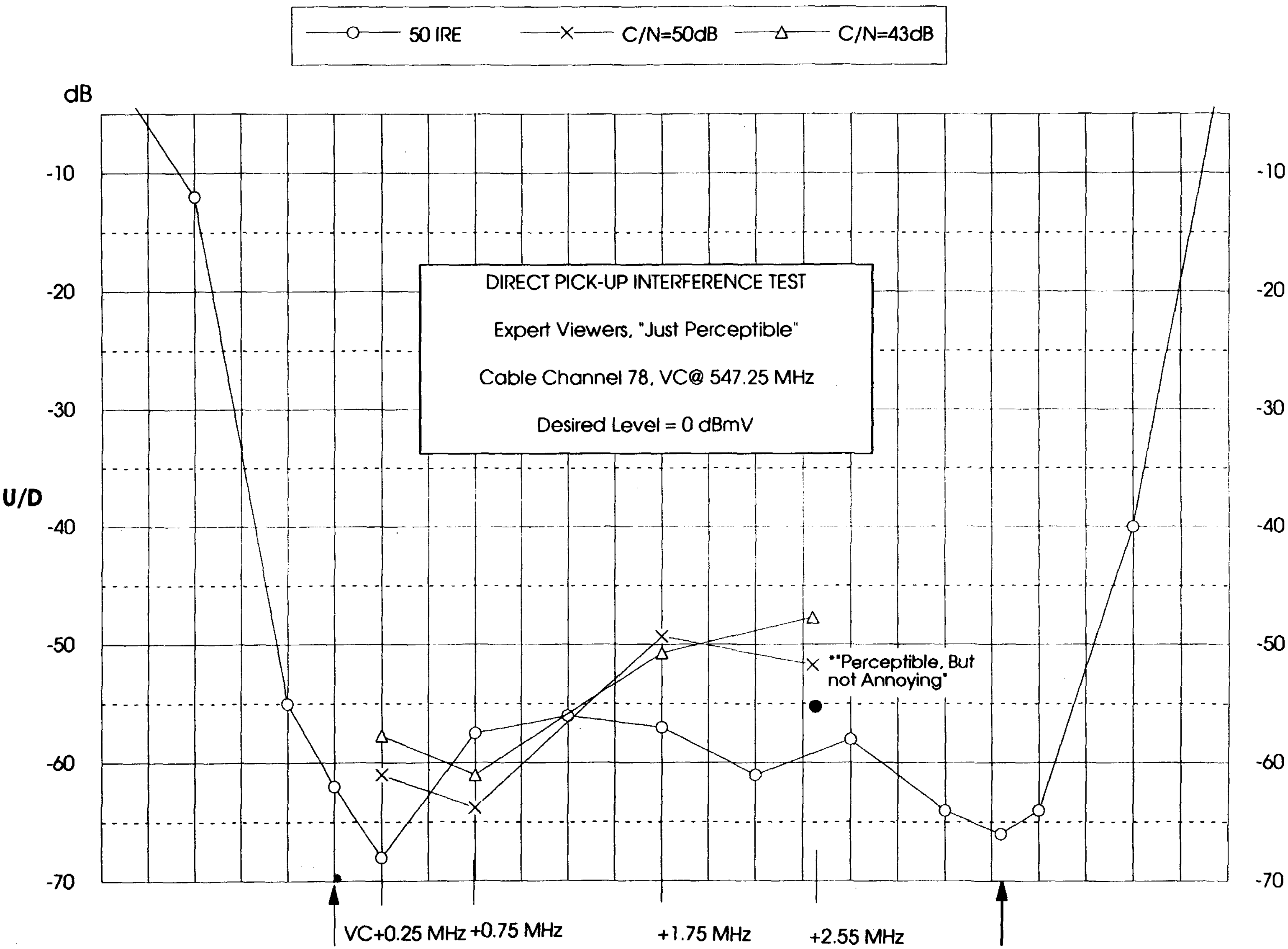

50 IRE
C/N=50dB
C/N=43dB
dB
U/D
-10
-20
-30
-40
-50
-60
-70
DIRECT PICK-UP INTERFERENCE TEST
Expert Viewers, "Just Perceptible"
Cable Channel 6, VC@ 83.25 MHz
Desired Level = 0 dBmV
"Midway Between "Imperceptible" and "Perceptible, But not Annoying"
VC+0.25 MHz +0.75 MHz
+1.75 MHz
+2.55 MHz
Visual Carrier
Color Subcarrier

Figure 2



50 IRE
C/N=50dB
C/N=43dB
dB
U/D
-10
-20
-30
-40
-50
-60
-70
DIRECT PICK-UP INTERFERENCE TEST
Expert Viewers, "Just Perceptible"
Cable Channel 12, VC@ 205.25 MHz
Desired Level = 0 dBmV
*Midway Between "Perceptible, But not Annoying" and "Slightly Annoying"
VC+0.25 MHz
+0.75 MHz
+1.75 MHz
+2.55 MHz
Visual Carrier
Color Subcarrier

Figure 3



50 IRE
C/N=50dB
C/N=43dB
dB
U/D
-10
-20
-30
-40
-50
-60
-70
DIRECT PICK-UP INTERFERENCE TEST
Expert Viewers, "Just Perceptible"
Cable Channel 78, VC@ 547.25 MHz
Desired Level = 0 dBmV
•"Perceptible, But not Annoying"
VC+0.25 MHz
+0.75 MHz
+1.75 MHz
+2.55 MHz
Visual Carrier
Color Subcarrier

Figure 4

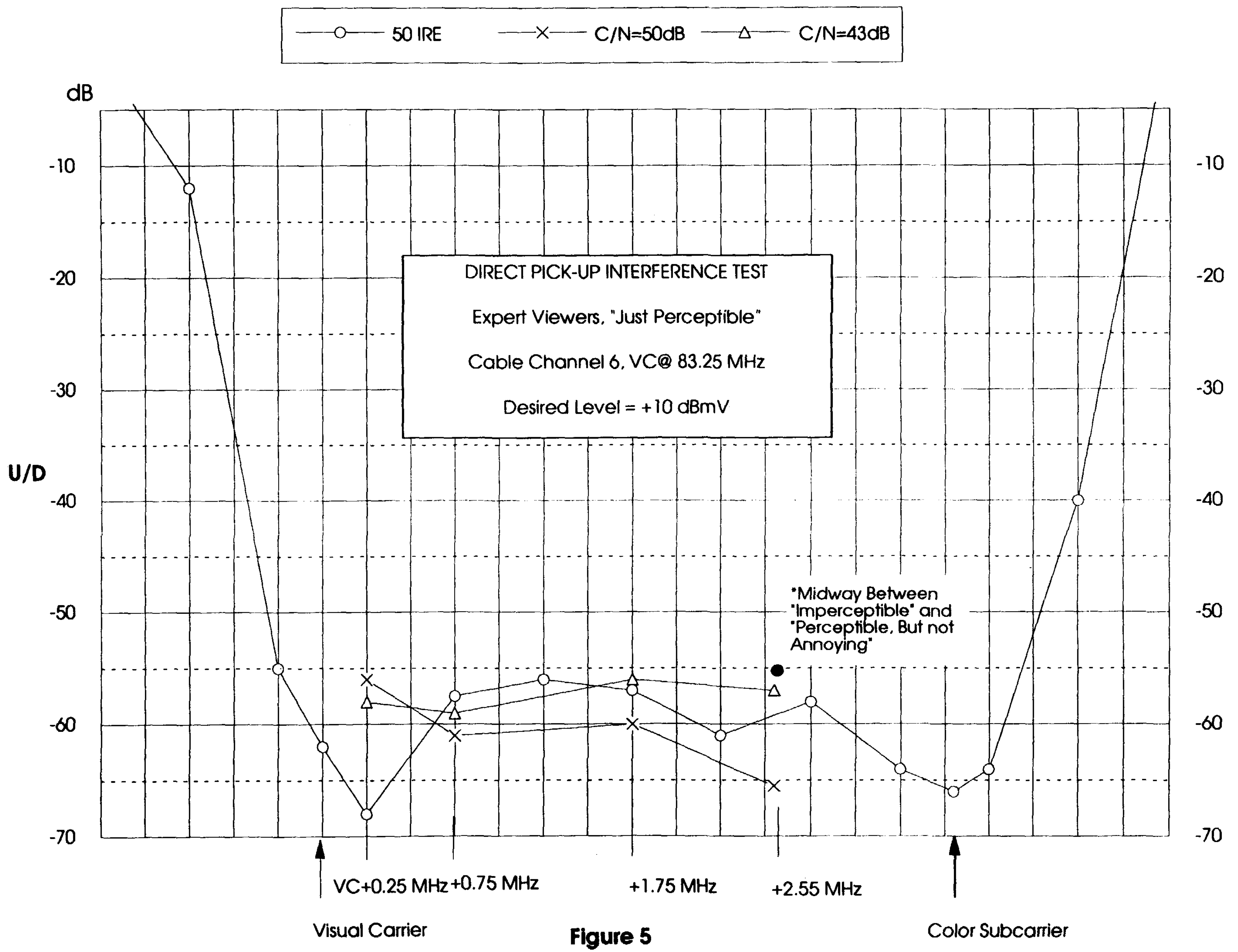
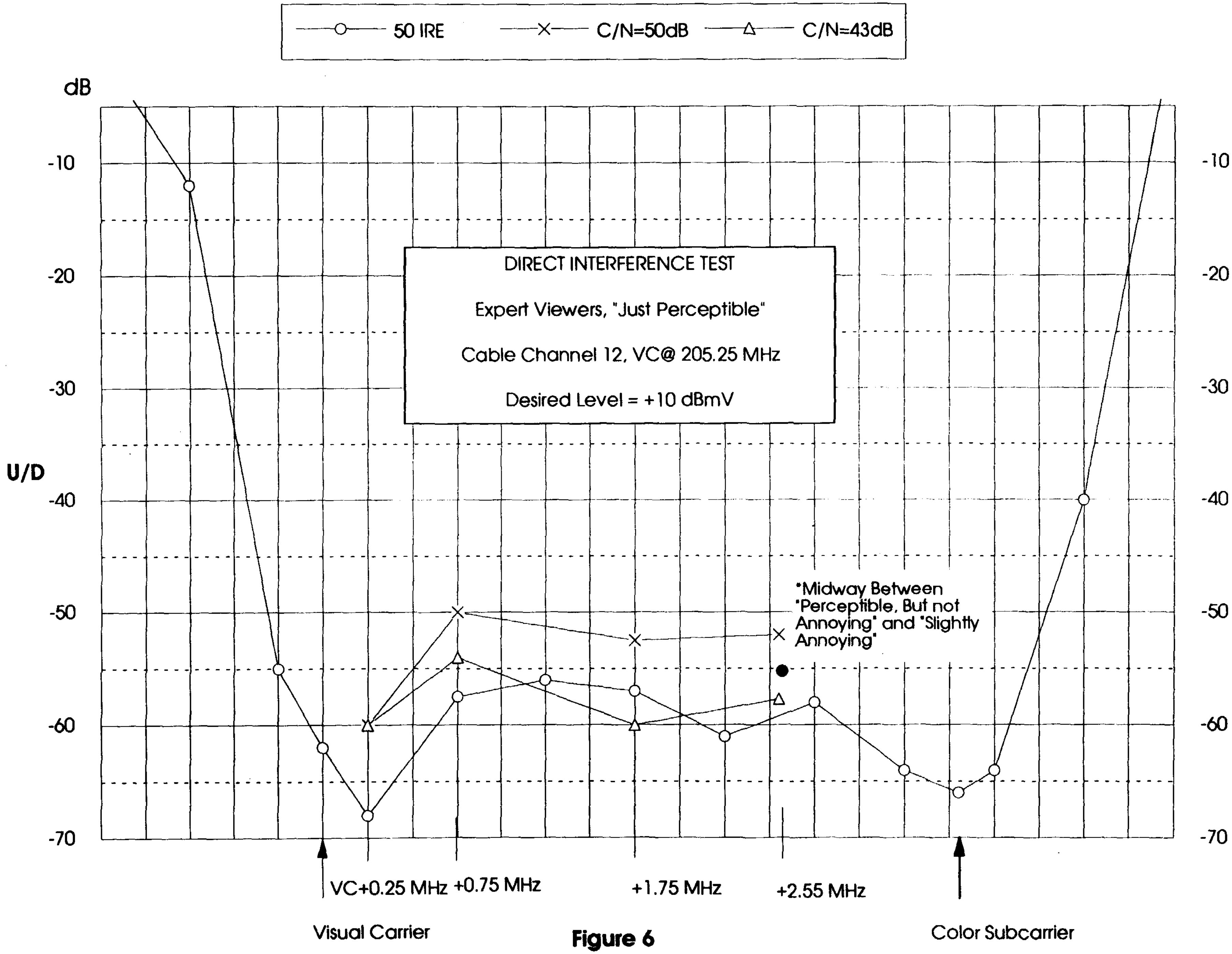

50 IRE
C/N=50dB
C/N=43dB
dB
U/D
-10
-20
-30
-40
-50
-60
-70
DIRECT PICK-UP INTERFERENCE TEST
Expert Viewers, "Just Perceptible"
Cable Channel 6, VC@ 83.25 MHz
Desired Level = +10 dBmV
"Midway Between "Imperceptible" and "Perceptible, But not Annoying"
VC+0.25 MHz
+0.75 MHz
+1.75 MHz
+2.55 MHz
Visual Carrier
Color Subcarrier

Figure 5



50 IRE
C/N=50dB
C/N=43dB
dB
U/D
-10
-20
-30
-40
-50
-60
-70
DIRECT INTERFERENCE TEST
Expert Viewers, "Just Perceptible"
Cable Channel 12, VC@ 205.25 MHz
Desired Level = +10 dBmV
*Midway Between "Perceptible, But not Annoying" and "Slightly Annoying"
VC+0.25 MHz
+0.75 MHz
+1.75 MHz
+2.55 MHz
Visual Carrier
Color Subcarrier

Figure 6

VIEWER RATING OF CTJC -55 dB TEST FRQUENCY
(C/N = 50 dB)

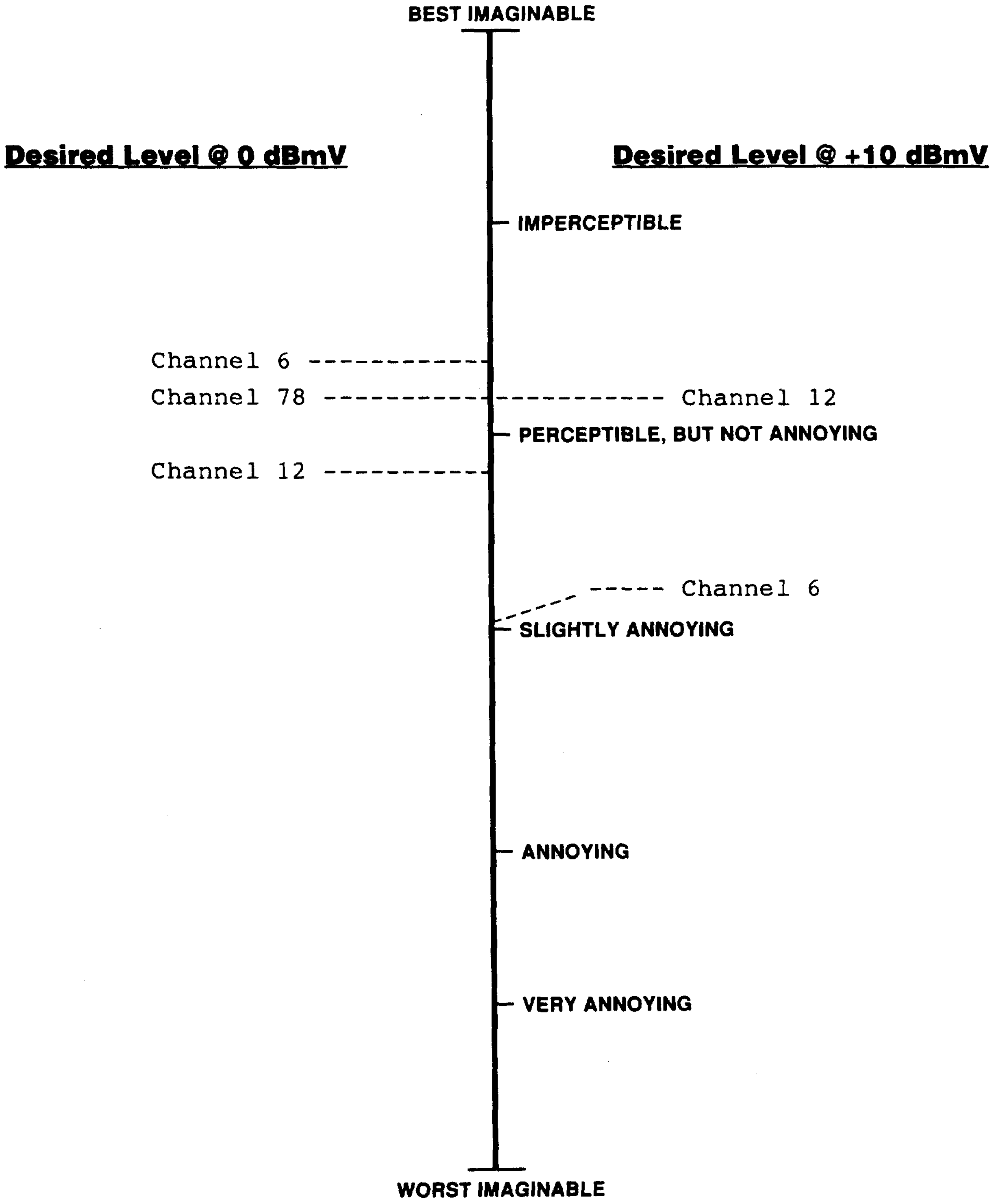


Figure 7

Frequency*	**Channel 6**		**Channel 12**		**Channel 78**
C/N = 50 dB		*+10 D*		*+10 D*	
VC+0.25,	-56.5 dB	*[56]*	-65 dB	*[60.5]*	-61 dB
VC+0.75,	-51	*[61]*	-54	*[54.5]*	-63.8
VC+1.75,	-55	*[60]*	-54	*[60]*	-49.3
VC+2.55,	-54	*[65.5]*	-57	*[56.5]*	-51.7
C/N = 43 dB					
VC+0.25,	-59	*[58]*	-63	*[60]*	-57.7
VC+0.75,	-47.5	*[59]*	-54.3	*[50]*	-61
VC+1.75,	-49.4	*[56]*	-53	*[53]*	-50.7
VC+2.55,	-47.4	*[57]*	-57.7	*[52]*	-47.7

* Visual Carrier (VC) of

CH 6	@	83.25	MHz
CH 12	@	205.25	MHz
CH 78	@	547.25	MHz

Desired Level = 0 dBmV except where italicized

Carrier to Noise (C/N) measured at the input to the receiver

TABLE 1: "JUST PERCEPTIBLE" IMPAIRMENT LEVELS

THRESHOLDS (Just Perceptible)

	Non-Expert	Expert
CO-LUMA	63	64.4
CO-CHROMA	57.8	58.6

Attachment A

6.0 Appendices

CARL T. JONES CORPORATION

MITIGATING FACTORS

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7901 Yarnwood Court, Springfield, Virginia 22153-2899 (703) 569-7704 Fax: (703) 569-6417

Mitigating Factors

The FCC's F(50,50) propagation curves predict the field strength, at a given distance from a transmitting antenna, which will be received at 50% of the locations at least 50% of the time. The F(50,50) propagation curves were empirically derived, based on a large number of measurements performed on various television and radio broadcast stations throughout the United States. The F(50,50) propagation curves are based on outdoor receive locations and a receive antenna height nine meters above local ground level.

In evaluating the impact of DPU interference, it is desirable to predict the interfering field strength at the television receiver location. The receiver location is indoors and may be at a height different than the nine meter height used in the derivation of the F(50,50) curves. Further, the majority of DPU interference occurs in urban or suburban environments where there is a high density of manmade structures. These additional structures may act to attenuate the interfering signal to a greater extent than is predicted by the FCC's curves.

In this section, three mitigating factors are discussed: receiver height-gain, building attenuation, and urban and suburban clutter.

Receiver Height-Gain Factor

As was stated above, the FCC's F(50,50) curves are based on a receive antenna height of nine meters above local ground level. Since we are interested in determining the ambient field strength at the actual receiver height, it is desirable to establish a correction factor for receive heights other than nine meters. For example, a typical television receiver location on the first floor of a single family dwelling may be only two meters above local ground level. On the other hand, a receiver located on an upper floor of a high-rise apartment building may be at a height significantly greater than nine meters.

The ratio of two received field strengths, f_1 and f_2, measured at two different receive heights, h_1 and h_2, is referred to as the height-gain. Lee[1] presents empirically derived equations which express the height-gain, logarithmically, for a reference height, h_1, equal to three meters as follows:

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[1]William C.Y. Lee, Mobile Communications Design Fundamentals (Indianapolis: Howard W. Sams & Co., 1986), 66-74; 220-221.

$$G_h = 10\log(h_2/3) \quad for\ h_2 < 3 \qquad (eq.\ 1)$$

and

$$G_h = 2h_2\log(h_2/3) \quad for\ 3 < h_2 < 10 \qquad (eq.\ 2)$$

where G_h = height-gain (dB)
h_2 = actual height of receiver (meters)

The height-gain equations above are graphically presented in Figure 1. In this graphic presentation, a receive height of nine meters has been chosen as the reference height to correspond with the receive antenna height used in the derivation of the F(50,50) curves. A linear relationship is used in the graph of for heights above 10 meters. The height-gain equation for heights above 10 meters can be expressed logarithmically as follows:

$$G_h = 20\log(h_2/10) \quad for\ h_2 > 10 \qquad (eq.\ 3)$$

The use of Figure 1 allows for the prediction of field strength at receiver heights other than nine meters by first determining the field strength at nine meters, through use of the F(50,50) curves, and then adding the height-gain correction factor for the actual height of the receiver. Note that the height-gain factor can be either positive or negative dependent on whether the actual receiver height is above or below nine meters. Should the height-gain correction factor result in a field strength value which exceeds the free space value, the free space value should be used.

Building Attenuation Factor

The F(50,50) propagation curves are based on outdoor receive locations; however, from a DPU interference standpoint, we are interested in the ambient field strength at the indoor location of the television receiver. Building attenuation is a second mitigating factor which may result in a reduction in the predicted ambient field strength at the actual receiver location.

The results of several measurement programs, designed to quantify building attenuation, are reported in the literature. The attenuation is generally determined by first measuring the field strength of a transmitted signal at multiple locations just outside of the building under study, at ground level. The measurements are repeated at multiple locations inside of the building on one or more floors. The ratio of the average outside field strength to the average inside field strength is defined as the building attenuation. The building attenuation factor is typically expressed logarithmically.

Cox et al.[2] performed measurements in and around eight suburban homes to quantify attenuation to vertically polarized signals at a frequency of 800 MHz. A large number of measurements were made outside of each home, inside on the first and second floors, and in the basement. Regression analysis was used to analyze the data.

The findings of the study showed that the average building attenuation on the first floor was 5.5 dB, on the second floor -0.5 dB, and in the basement 14.3 dB. The negative attenuation or gain measured on the second floor indicates that the height-gain factor for measurements made on the second floor exceeded, on the average, the building attenuation factor.

Wells[3] reported on measurements of the average building attenuations for a large number of single family dwellings. The transmitting sources for these measurements were satellites having elevation angles between 36.1 and 55.4 degrees. These high elevation angles are similar to the condition of a dwelling in close proximity to a tall broadcast tower. At 860 MHz, the lowest frequency studied, the average attenuation to vertically polarized signals was 4.6 dB, and the average attenuation to horizontally polarized signals was 6.4 dB. These attenuation factors are in close agreement with the attenuation factor of 5.5 dB reported by Cox.

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[2] D. C. Cox et al., "800-MHz Attenuation Measured In and Around Suburban Houses," AT&T Bell Laboratories Technical Journal, Vol. 63, No. 6 (July-August, 1984), 921-955.

[3] Paul I. Wells, "The Attenuation of UHF Radio Signals by Houses," IEEE Transactions on Vehicular Technology, Vol. VT-26, No. 4 (November, 1977), 358-362.

Smith[4] reported on measurements made of the attenuation of electric and magnetic fields by buildings over the frequency range from 20 kHz to 500 MHz. Smith developed a fitted attenuation curve for each building studied, which describes the building attenuation as a function of frequency.

Two single family detached residences were studied: Building 1 is described by Smith as having wood and brick exterior, and Building 2 is described as having aluminum siding exterior on the upper level and concrete block with brick veneer exterior on the lower level. For the frequencies between 50 MHz and 500 MHz (cable frequencies), the fitted curve for electric field attenuation for Building 1 ranged from approximately 0 dB to 7.5 dB. For Building 2, over the same frequency band, the electric field attenuation curve had a minimum value of 5.5 dB and a maximum value of 12.5 dB.

Walker[5] reports on building attenuations in three urban and eleven suburban multi-story office buildings in the greater Chicago metropolitan area. Attenuations in these buildings should be similar to that of multi-story apartment buildings. Measurements were performed in the 850 MHz cellular frequency band. Average building attenuation on the first floor of the urban buildings was found to be 18 dB, while the average attenuation on the first floor of the eleven suburban office buildings was 13.1 dB. The overall average attenuation for first floor location was 14.2 dB.

Walker reported further on the effect of the floor height-gain by plotting measured average attenuation versus building floor for the 14 buildings studied. A "least squares" straight line fit applied to the data resulted in a slope of 1.9 dB per floor. That is, the attenuation was found to decrease with increasing floor height at a rate of 1.9 dB per floor. The straight line fit intersects 0 dB attenuation between the sixth and seventh floors. This is the floor height at which the height-gain factor is equal but opposite to the building attenuation factor such that the average field strength within the building at this level is equal to the average field strength outside of the building at ground level.

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[4]Albert A. Smith, Jr., "Attenuation of Electric and Magnetic Fields by Buildings," IEEE Transactions of Electromagnetic Compatibility, Vol. EMC-20, No. 3 (August, 1978), 411-418.

[5]E. H. Walker, "Penetration of Radio Signals into Buildings in the Cellular Radio Environment," The Bell System Technical Journal, Vol. 62, No. 9 (November, 1983), 2719-2734.

Rice[6] reports on measurements made in and around eleven multi-story office buildings in downtown New York City at 35 MHz and 150 MHz. The overall average attenuation on the first floor of the buildings studied was found to be 24 dB at 35 MHz and 22 dB at 150 MHz. Rice also provides a graph of building attenuation versus height above street level. Assuming a per floor height of 12 feet, the graph indicates that building attenuation decreases with increasing floor height at a rate of approximately 3 dB per floor between the second and tenth floors. The graph shows no decrease between the first and second floors. The straight line fit intersects 0 dB attenuation between the eighth and ninth floors, or two floors above the 0 dB intercept point found by Walker.

In summary, based on the literature, average building attenuations on the first floor of suburban homes ranged from 0 dB to 12.5 dB. In urban and suburban buildings, average building attenuations, for first floor locations, ranged from 13.1 dB to 24 dB. Further, the effect of building attenuation decreases with increasing floor height at a rate of between 1.9 dB and 3 dB per floor.

Urban and Suburban Clutter Factor

The high density of man-made structures in urban and suburban locations is known to increase path loss for mobile radio transmissions. A brief study was undertaken to evaluate whether or not an additional urban and/or suburban attenuation factor should be applied in predicting DPU interference levels.

Lee[1] presents a slope-intercept model for propagation in urban and suburban areas in the United States. Specific empirically derived parameter values are given for Philadelphia and Newark, as well as general parameter values for U.S. suburban areas. Based on this model, a graph of field strength versus distance was developed for the Philadelphia urbanized area (Figure 2) for a 100 KW ERP broadcast facility with an antenna height above average terrain of 305 meters (1,000 feet). This antenna height is typical for high powered television broadcast stations in the eastern United States.

For comparison purposes, two additional graphs of field strength versus distance are also shown in Figure 2; one graph is based on free space loss and the second graph is based on the FCC's F(50,50) propagation curves. Each of the three graphs is based on a receive antenna height of nine meters.

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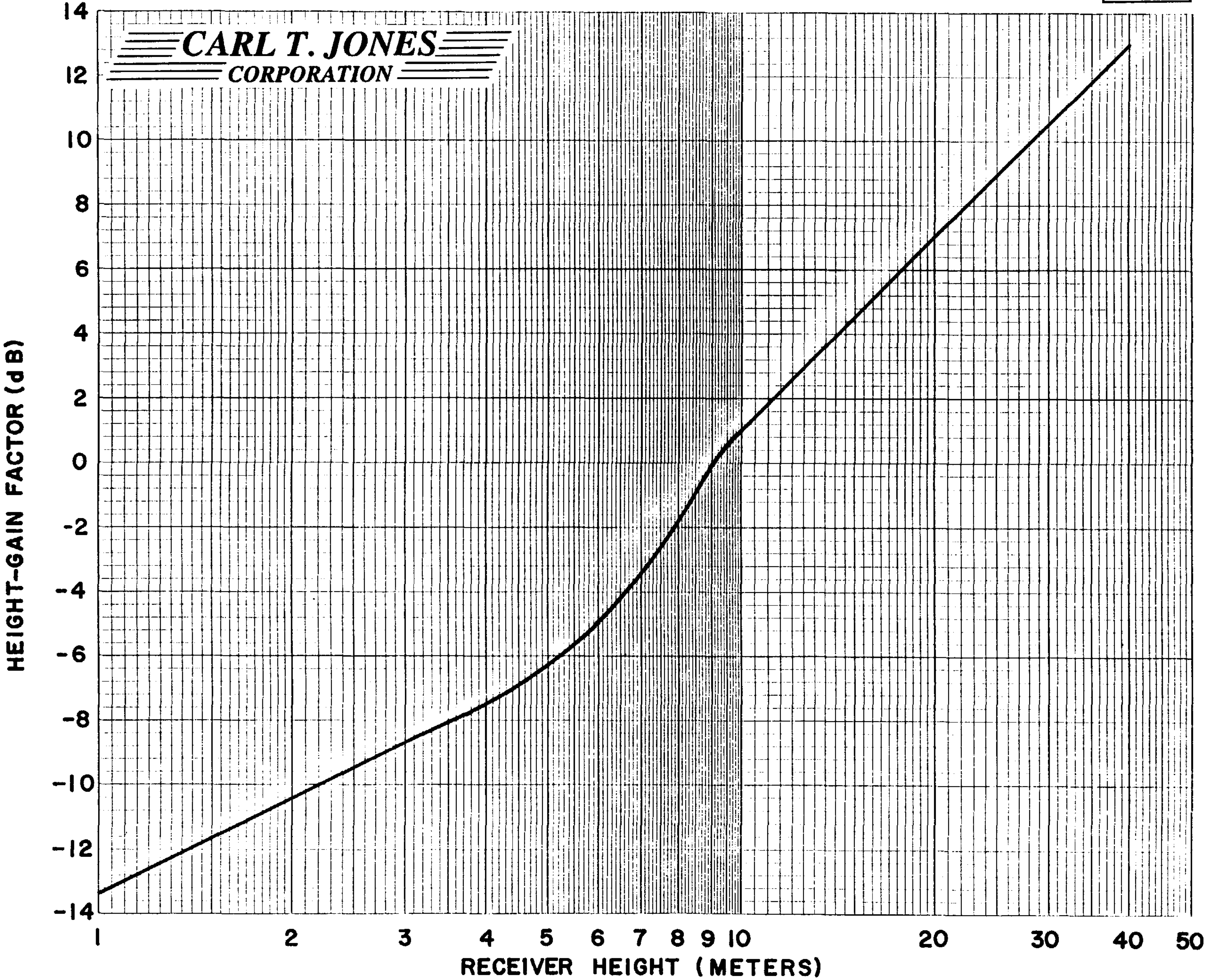
[6] L. P. Rice, "Radio Transmission into Buildings at 35 and 150 mc," The Bell System Technical Journal (January, 1959), 197-211.

Figure 2 indicates that Lee's urban propagation model predicts a slightly higher field strength than the FCC F(50,50) curves for distances less than two miles from the transmit antenna and a lower field strength for distances between 2 and 20 miles from the antenna. The greatest difference between the two graphs is approximately 4 dB. It should be pointed out that in deriving the urban field strength curve shown in Figure 2, the value of the model variable, n, was chosen to be 20 dB/decade which results in the lowest prediction of field strength. Lee indicates that this variable can range from 20 to 30 dB/decade. Selection of higher values of n can result in the predicted field strength being greater than the field strength predicted by the F(50,50) curves over the entire distance shown.

Based on the urban area slope-intercept model described by Lee, it appears that an additional attenuation factor of 0 to 4 dB may be appropriate for urban areas in the United States. No additional factor is recommended for suburban areas.

FIGURE 1



CARL T. JONES
CORPORATION
HEIGHT-GAIN FACTOR (dB)
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
1
2
3
4
5
6
7
8
9
10
20
30
40
50
RECEIVER HEIGHT (METERS)

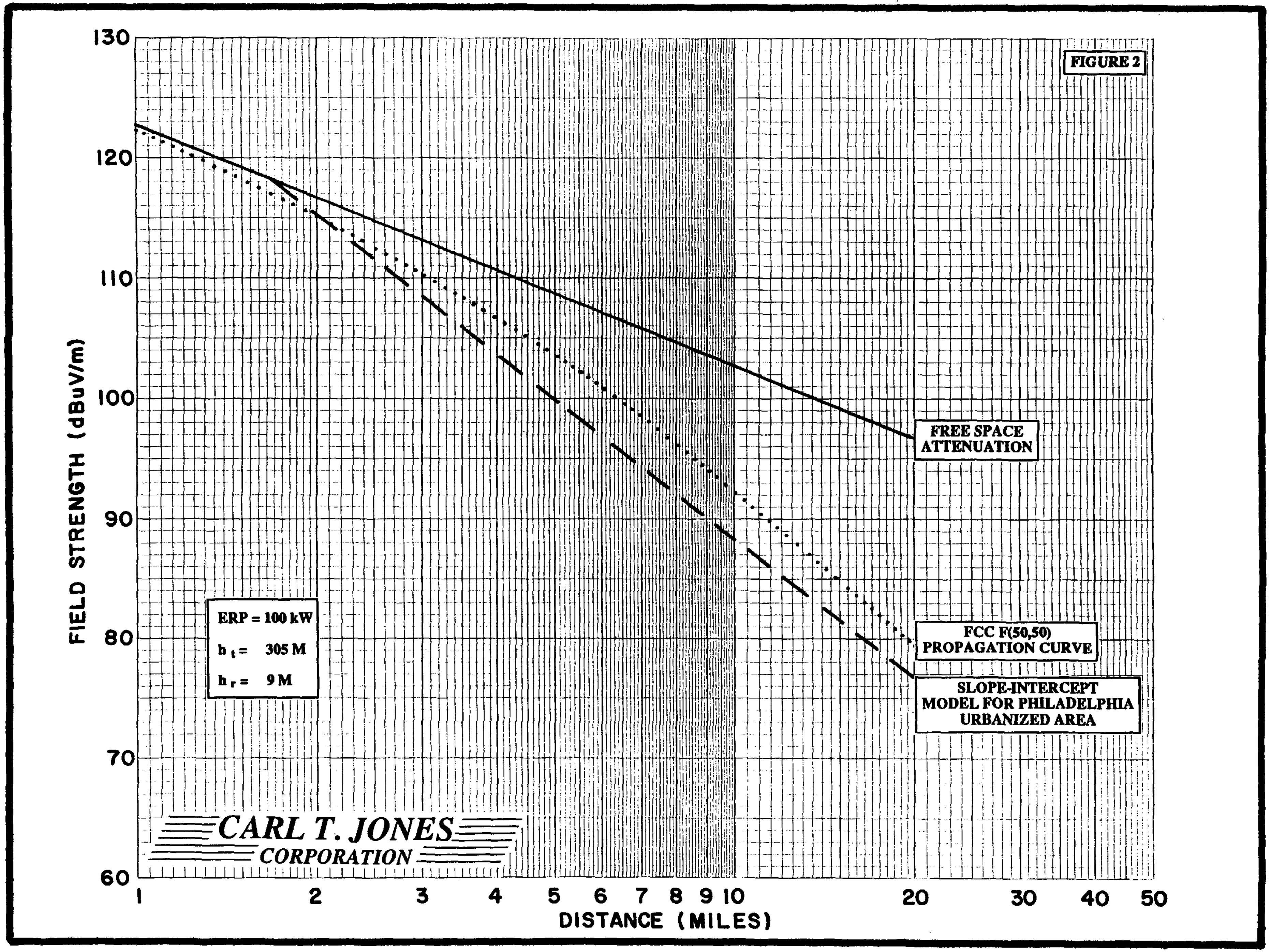


FIGURE 2
FIELD STRENGTH (dBuV/m)
130
120
110
100
90
80
70
60
DISTANCE (MILES)
1
2
3
4
5
6
7
8
9
10
20
30
40
50
FREE SPACE ATTENUATION
FCC F(50,50) PROPAGATION CURVE
SLOPE-INTERCEPT MODEL FOR PHILADELPHIA URBANIZED AREA
ERP = 100 kW
h t = 305 M
h r = 9 M
CARL T. JONES CORPORATION